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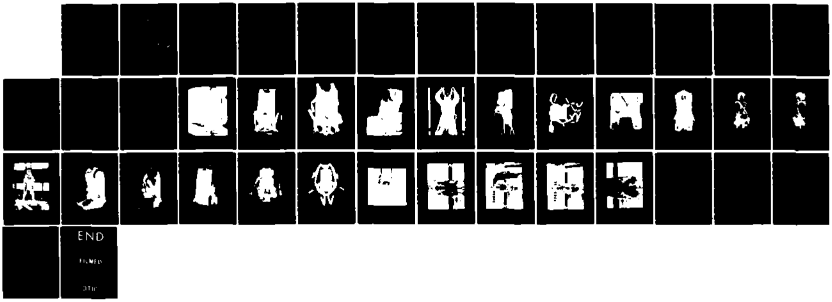

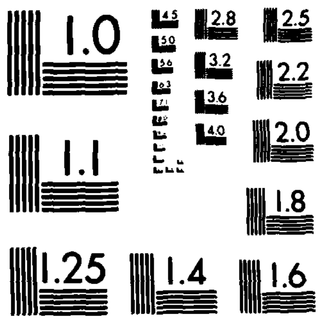
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REPORT NO. NADC-84114-60

AD-A151 909

IMPROVING INFLIGHT NEGATIVE Gz RESTRAINT FOR AIRCREWMEN

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Inadequate negative Gz restraint has been cited as a factor preventing pilots from recovering control of their aircraft after a departure from positive G maneuvers.

Several prototype XV seat-mounted harnesses were designed and tested to determine if they might provide improved inflight restraint. Although they were able to improve restraint, none of them could meet the rigid and conflicting demands which were imposed.

The restraint which met most of the requirements was the MA-2 Torso Harness with the addition of a seat-mounted 'Y' shoulder strap. The 'Y' strap reduced average head displacement to about one-third of its former value (from 6cm to 2cm for a 50% subject at -1Gz). No problems were uncovered during seat/man separation tests, and the 'Y' strap did not restrict upper torso rotation.

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BACKGROUND ON OPERATIONAL DEFICIENCIES

High performance fighter aircraft placed in a tight turn can develop an asymmetrical stall pattern over the wing. This rolls the aircraft into a departure from positive G controlled flight. Unless the aircraft is very stable it will not recover without corrective action by the pilot. It is therefore essential that the pilot be securely restrained in his seat especially for -Gz acceleration (lifting the aircrewman off of his seat) otherwise he could be thrown too far out of position to obtain the full range of control stick motion required for recovery.

Improving negative Gx restraint (forcing the aircrewman forward in his seat) is also important in aircraft that develop flat spins after a departure. This, however, is an inertia reel problem and can be corrected by modifying the reel to quickly lock when it senses -Gx; the present reel senses rate of strap play-out and locks between 2 and 3 G which may not be soon enough in the spin condition.

The present fighter restraint harness (MA-2 Torso Harness) was introduced into the service around 1960. It has proven to be an excellent parachute harness but many reports have indicated that it is inadequate for -Gz restraint (reference 1). Over the past two decades several aircraft losses have been directly attributed to this problem.

TESTS ON PREVIOUSLY PROPOSED MA-2 HARNESS MODIFICATIONS

The Naval Air Systems Command initiated a program to determine if any previously proposed modifications to the MA-2 harness or any existing seat-mounted harnesses would provide a significant reduction of aircrewman displacement during -Gz acceleration (The operational MA-2 harness at -1 Gz allows the head to displace between 6cm to 12cm depending on the aircrewmember percentile and lap belt tension.

The test program conducted at the Naval Air Development Center (NAVAIRDEVCEN) (reference 2) and at the Naval Air Test Center (NAVAIRTESTCEN) (reference 3) indicated that the simplest modification to the MA-2 was a 'fifth strap' connecting the lap belt to the front edge of the ejection seat (figure 1). Unfortunately, this strap could only provide an average improvement of one centimeter at -1 Gz when the lap belt was worn tight. This was not significant enough to warrant a retrofit effort. The U.S. Air Force also tested their torso restraint system with a fifth strap and the results were in agreement with the U.S. Navy tests (reference 4).

TESTS WITH COMMERCIALLY AVAILABLE SEAT-MOUNTED HARNESSES (figures 2 and 3)

Tests with seat-mounted harnesses indicated that they could provide a two- to three-centimeter reduction of head displacement at -1 Gz if the straps were properly adjusted (reference 3). Unfortunately, the two commercially available seat-mounted harnesses (the British Simplified Combined Harness and the German Alpha-jet Harness) had too many disadvantages for present U.S. Navy requirements;

a. Neither harness could be retrofitted with the Navy's latest SEAWARS/KOCH automatic parachute release fittings which actuate on water immersion (figure 4).

b. The Alpha-jet harness was very difficult to adjust, this may lead to its being worn too loose by most pilots and therefore would prove to be ineffective as a restraint or parachute harness.

c. Neither harness provided upper torso support during ejection acceleration (reference 5); it was very easy to rotate forward under the shoulder straps even when the inertia reel was fully retracted and locked. This might cause an increase in spinal injuries during ejection.

d. In their present configurations the harnesses require the crewmember to wear a man-mounted survival vest equipped with life preserver, signal gear, and built-in helicopter lift sling. When all of this equipment is worn, the aircrewman is almost as encumbered in and out of the aircraft as he would be wearing the present MA-2 torso harness.

e. If some of the life support equipment were transferred onto the seat-mounted harness, it could not be equipped with a water immersion actuator because the equipment would be lost with the harness upon separation from the man.

The major advantage of the two seat harnesses tested was their logistics improvement (i.e., one harness per seat versus one per aircrewman) but they did little to improve performance, safety, or comfort.

DESIGN SPECIFICATIONS FOR IMPROVED RESTRAINT HARNESS

Since neither the existing modifications to the MA-2 torso harness nor the two commercially available seat-mounted harnesses offered a quantum improvement in flight performance or safety it was evident that some new ideas would have to be tried. In order to have some goal it seemed worthwhile to set up some design objectives even though there was the realization that they could not all be met (i.e., some desirable features are in strong conflict with other desirable features).

1. Seat-mounted harness; one size fits third through ninety-eight percentile pilot population (shoulder height, seated position).

2. The crewman shall be able to egress from the seat to a standing position free of all attachments to the aircraft survival kit, and parachute within 5 seconds.

3. Negative Gz restraint will be sufficient to restrain a fifty percentile subject such that his average head displacement is less than 5cm at -1 Gz. The test subject will adjust his harness so he can look 180 degrees both left and right before the inverstion test. Five inversions will be conducted with the test subject readjusting the straps each time.

4. The harness will incorporate an automatic water immersion release of the parachute (preferably the existing SEAWARS/KOCH fittings).

5. The LPU-23P life preserver will be mounted on the harness but shall be easily removed for maintenance.

6. A lift support will be provided so the crewman with wet equipment can be easily lifted into a rescue helicopter.

7. A flare/smoke signal, strobe light, and signal mirror will be mounted on the harness.

8. The survival kit shall hang from the harness during parachute descent so as not to interfere with the landing as compared to the existing MA-2 harness/survival kit arrangement; it shall not degrade performance.

9. The harness should not allow excessive slumping or submarining of the aircrewman during ejection.

10. Parachute opening shock loads should not cause injury because of strap routing or loose fittings.

11. The harness should be designed with enough closed cell foam to make the harness assembly (with uninflated preserver) positively or neutrally buoyant.

12. The harness will be able to be installed in existing ejection seats with minimal modification to seats, survival kits, and life support equipment.

No strong requirement was made for a 'single point release' of the aircrewman. Although this feature is desirable it appears impractical to attain in a retrofittable harness. It tends to drive the entire design and causes severe compromises with other harness requirements. The objective was quick release and an improvement over the current MA-2 rather than single point release.

WEIGHTED DESIGN TRADEOFFS

In addition to improving inflight restraint, consideration should be given to improving logistics as well (i.e., to provide one seat-mounted harness in place of the fifteen different sizes of the MA-2 torso harness presently in stock). Of course a single universal fitting restraint means that aircrewmen could fly with a very loose harness if they chose to do so. Unfortunately, most of the other features listed above were also countered by some conflicting requirement. Obviously many design tradeoffs have to be made to obtain the best compromise to meet the aircraft mission as well as crewman safety.

The 'Importance Factors' on the following Tradeoff Factors were determined after discussing them with Navy pilots:

Tradeoff Factors	Importance Factors
1. Mission Effectiveness	
A. Rotational Mobility for ACM	10
B. Seated Comfort	9
C. Improved -Gz Restraint	8
D. Improved -Gx Restraint (inertia reel)	8
E. Ease of Adjustment	5
F. Ingress Time	2
2. Safety	
G. Landing in Water.... Automatic Chute Release	10
H. High Q Arm Restraint	8
I. Landing on Ground.... Ease of Chute Release	7
J. Ease of Climbing into Raft	7
K. Ease of SAR Pickup	7
L. Back Support for Ejection	6
M. Reduction of Parachute Shock Loads	5
N. Emergency Ground Egress Time Reduction	5
O. Easy Access to All Survival Gear for Escape and Evasion	5
P. Functional Comfort in Raft	4
Q. Ability to Handle High Crash Loads	3

		Importance Factors
3.	COST AND LOGISTICS	
S.	Acceptability by Aircrewmen	7
T.	Use Existing Life Support Equipment with Little Modification	6
U.	Maintainability	6
V.	Retrofit Cost	4

ATTEMPTS TO DEVELOP A SEAT-MOUNTED HARNESS

With these specifications and tradeoffs as guides a design of a seat-mounted harness called the XV (Ex-Vee) Restraint (reference 6) was started. The 'X' describes the upper torso configuration, and the 'V' describes the lower torso straps going over each thigh.

Earlier investigations by NAVAIRTESTCEN indicated that secure -Gz support required both upper torso and lower torso restraint (reference 1). The MA-2 Harness only provides lower torso -Gz restraint.

There seemed to be only two simple ways to obtain the required upper torso restraint yet allow the crewman rotational mobility essential for combat—either a 'Y' strap, or an 'X' strap system with slip fittings.

A 'Y' strap routing in front of the crewman permits him to freely turn on the single central strap; this is somewhat like the routing of the Simplified Combined Harness which was one of the two seat mounted harnesses tested. The other arrangement utilizes 'X' cross chest straps. Anchor points to the seat or survival kit are located near the crewman's hip joints. Straps route up from these anchor points (figures 5 through 20). As the crewman turns in his seat the cross chest straps are free to slide through the slip fittings. Unfortunately, both of these upper torso strap routings have shortcomings for parachute loads; the risers tend to move in too close to the crewman's head. If the risers are equipped with disconnect/adjuster fittings there is a good chance that they will strike the crewman's face during parachute deployment. Because of this problem both of these strap routings proved unacceptable when mated with the SEAWARS/KOCH parachute release fittings (figures 7, 14, 20).

The first prototype XV harness (figures 5 through 10) had manual/automatic release fittings on either side of the crewman's hips. The harness, parachute, and survival kit were all removed automatically on water immersion. Because the links on either side of the crewman's head were very small there was little chance that these low mass riser fittings would injure the crewman. Although this prototype had a great deal of potential it was abandoned because the decision was made that any new seat-mounted harness design must utilize the newly developed SEAWARS/KOCH fittings and the life support equipment must be harness mounted.

The second XV prototype harness (figures 11 through 14) utilized the SEAWARS/KOCH fittings. It proved unsatisfactory because these fittings could strike the crewman's head during parachute suspension.

The third prototype (figures 15 through 20) was designed to reduce the angle of the cross chest straps in order to keep the release fittings from pulling in too close to the crewman's head. This design was unable to correct the head strike problem. The only safe way to mount these large release fittings appeared to be with an arrangement similar to the MA-2 torso harness where the risers come straight up the sides with no component force pulling them to the center.

NEW MODIFICATIONS TO THE MA-2 TORSO HARNESS—THE 'Y' STRAP (figure 21)

Since none of the seat-mounted harnesses tested could meet important objectives without severely compromising essential functions it was decided to take a fresh look at the MA-2 harness and see if some new approach might improve it. A 'Y' strap upper torso restraint added on top of the MA-2 harness was found to provide excellent -Gz restraint without restricting rotation, and was very simple to retrofit since no modification was required to either the seat or life support equipment.

TESTS ON 'Y' STRAP

NEGATIVE Gz

Procedure

Three test subjects were used to evaluate the effectiveness of three configurations; the standard MA-2 (figure 22), the MA-2 with a fiberglass bearing pad lap belt (figures 23, 24), and the MA-2 with 'Y'-strap (figure 21). An MK-10 Martin-Baker ejection seat was used as a test platform. The seat was mounted on the NADC -Gz "rotisserie" (figure 22). Before each of the five inversions the test subjects loosened, then readjusted all straps.

Head displacement was measured with a sliding rod in contact with the top of the subject's head (figure 22). After the subject was inverted he was told to shake around to assure that no friction loads restrained him, only the straps provided restraint.

The Bearing Pad lap belt was tested in order to determine the effectiveness of the best possible lower torso restraint. The pad served to spread out the belt loading over large areas of the thighs so that these high loads were more tolerable.

The 'Y' strap was tested with and without a lap belt to determine its effectiveness.

Results

The results of all tests are shown in figures 25, 26, and 27. It can be seen that the head displacement for all three subjects was considerably reduced with the 'Y' strap.

There was not a great deal of improvement from the bearing pad because all the subjects had been tightening their lap belt just short of feeling pain; they couldn't tighten the belts much more with the pad. Pilots normally do not fly with their lap belt this tight, so head displacements under operational conditions could go as high as double the values shown. On the other hand, the 'Y' strap was never worn tight; all slack was removed without applying a preload. This is one of the advantages of the 'Y' strap; the crewman doesn't feel it once it is connected. It does not restrict motion in any directions other than the Z direction yet it holds him securely in his seat even if the lap belt is worn loose.

Normally the large subject would be expected to displace farther than a small subject when inverted because of higher loads on the straps, however since the test subjects tightened their own straps displacements varied between subjects regardless of size and weight.

During the tests with the ninety-five percentile subject a second set of displacement measurements was made with the lap belt disconnected. With only the 'Y' strap providing restraint the average head displacement was 4.4 cm; this is an increase of 1.2 cm; even with a very loose or disconnected lap belt the 'Y' strap alone can provide adequate negative Gz restraint.

SEAT/MAN SEPARATION

Procedure

Several tests were conducted on the 'Y' strap to determine which of several attachment configurations would prove best for safe seat/man separation during emergency egress and after ejection.

An ESCAPAC ejection seat with RSSK-8A seat kit was mounted on the NADC 'Rotisserie.' Seat/man separation was accomplished by pulling the emergency harness release handle. The following two sets of tests were done with each configuration: (1) the subjects pulled the handle, then stood up and pulled free of the seat; (2) a fifty-percentile dummy was released from the seat when it was in an inverted position.

Configurations Tested, and Results

The 'Y' strap consists of two lengths of webbing with loops at one end which fit over the back attachment tangs of the survival kit. These two shoulder straps cross behind the crewman's back, come over his shoulders, and plug into a junction fitting in front of the crewman's chest. A single adjustable length strap continues downward from this junction and attaches to the front of the seat or under the survival kit.

Forward Configuration 'A'

The forward strap connects to a 'V' junction, then both of these straps route under the survival kit and terminate in loops which also fit over the back attachment tangs of the survival kit. See figures 5 through 10.

During egress this arrangement occasionally hung up because the back strap loops and the front strap loops pull in different directions.

Forward Configuration 'B'

The forward strap routes through the seal between the survival kit lid and the pan. It terminates with the strap looped over a plastic dowel used to prevent the strap from pulling free from the kit unless the kit lid is opened. See figures 11 through 14.

This arrangement was tried to see if it was possible to retain the 'Y' strap until after the parachute was fully deployed to eliminate entanglement with the parachute.

During egress tests the two back loops of the 'Y' strap would slide off the survival kit tangs and allow the kit freedom to rotate aft. However, the front of the survival kit was restricted from rotating forward due to friction on the shoulder straps as they slid between the crewman and the parachute pack. This awkward position of the survival kit limited the crewman's ability to stand up. However, if the crewman were to actuate a 'Y' junction, release, then release both survival kit fittings, this would prove satisfactory.

Forward Configuration 'C'

The forward strap routed around the front of the survival kit, then underneath the kit, and terminated with a hollow nylon cylinder which prevented the strap from being pulled forward underneath the survival kit. See figures 15 through 20.

This arrangement appeared to offer the best separation of the crewman from the seat for both egress and ejection.

This 'Y' strap installation requires no major modifications to the seat, survival kit, or crewman's life support equipment, and it can be installed or removed in about ten minutes. The only modification to the seat would be the addition of two VELCRO tapes on the sides of the headbox to hold the shoulder straps in a convenient position as the crewman gets into his seat.

DISCUSSION

If the 'Y' strap is to be used as a retrofittable improvement to the existing MA-2 harness then the Y junction fitting should be designed with a single action, quick-release feature to simplify ground egress. This fitting must also incorporate an adjuster buckle.

The tiedown arrangement aft of the pilot could be cross back straps looped over the survival kit attachment tangs, or the straps could be made to form a 'Y' and the single vertical strap could route under the survival kit to terminate in a plastic cylinder just like the forward 'Y' strap in configuration 'C.'

The back straps should have short strips of VELCRO so they can be attached to the sides of the ejection seat headbox when the seat is unoccupied.

CONCLUSIONS

1. The 'Y' strap on top of the MA-2 harness provides a simple, effective, retrofittable -Gz restraint which still permits upper body mobility essential for air combat maneuvers.

When properly adjusted it does not interfere with normal crewman activities, it fits all sizes from 3rd to 98th percentile, and it can reduce the average head displacement of a 50-percentile aircrewman from 6cm down to 2cm at -1 Gz. This -Gz performance is as good as that provided by the Blue Angels aerobatic team harness—with the added feature of upper torso mobility which is missing in the aerobatic team harness.

2. The available (1984) seat-mounted harnesses offer no quantum improvement in flight performance, comfort, or safety which could justify the replacement of the existing MA-2 torso harness. Also, they are unsatisfactory for the U.S. Navy because they do not incorporate automatic parachute release upon water immersion, and they do not provide good torso support during ejection.

3. None of the prototype XV seat-mounted harnesses met the requirement to use the SEAWARS/KOCH parachute release fittings and also not hit the crewman's helmet during parachute opening shock.

4. An upper torso restraint is far more effective than a lower torso restraint in reducing head displacement during negative Gz maneuvers.

5. The 'Y' strap did not restrict ground egress or seat/man separation after ejection.

RECOMMENDATIONS

1. The 'Y' strap snould be evaluated by the Naval Air Test Center for its effectiveness in simulated air combat maneuvers. It should then receive additional evaluation by several operational squadrons.

2. If the 'Y' strap is favorably accepted then an Engineering Change Proposal can be prepared to incorporate this simple modification for any seat system requiring improved negative Gz restraint.

3. A 'Y' junction quick-release/adjuster fitting needs to be designed to make disconnect of the shoulder straps a single operation instead of two operations.

ACKNOWLEDGMENTS

This work could not have taken place without the enthusiastic support of many individuals. Thanks are due to: Dave Gold of NWC who has been a storehouse of information and ideas; Jim Rodrigez and Lisa Caluzzi of NATC for their test work; John Springer, Pete Butkus, and John Rudolph of NADC for fabrications of fittings; Marc Schwartz of NADC for managing all the paper transactions of this program; Rod Pursell for the fabrication of all experimental harnesses.

Both H. Koch & Sons and Teledyne McCormick Selph Corporation were extremely helpful; they provided quick disconnect adjuster fittings for several prototype harnesses.

Much of the test work was performed by Michael Schultz, Tim Ross and Yong Chang.

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Figure 1. Fifth Strap Added to MA-2 Harness

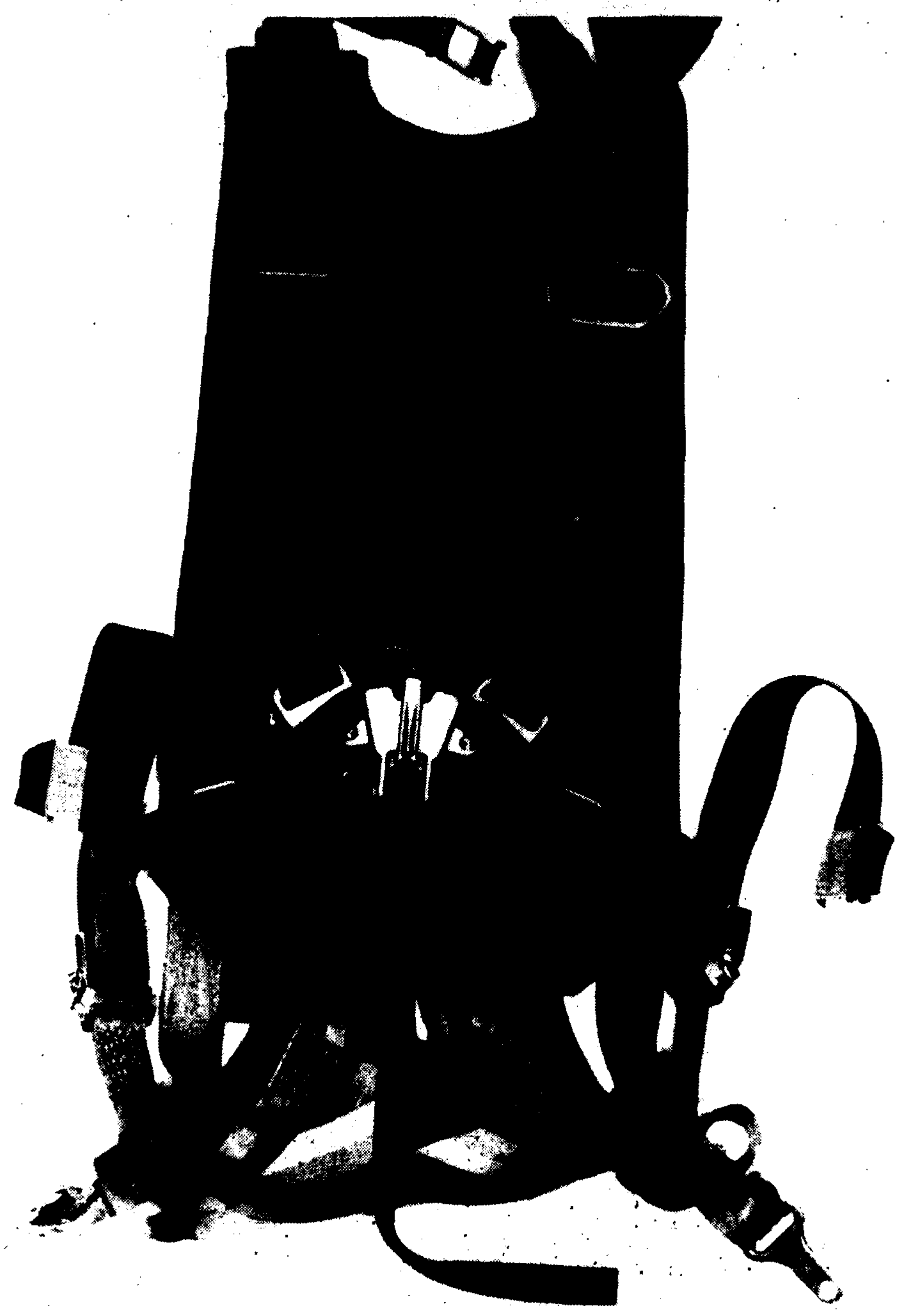

Figure 2. Martin-Baker Simplified Combined Harness

Figure 3. Alpha-Jet Seat-Mounted Harness

Figure 6. First Prototype XV Harness with Seat-Mounted Release Fittings (Side View)

Figure 7. First Prototype XV Harness–Parachute Suspension

Figure 8. First Prototype XV Harness–Survival Kit Attachment

Figure 9. First Prototype XV Harness—Expanded View

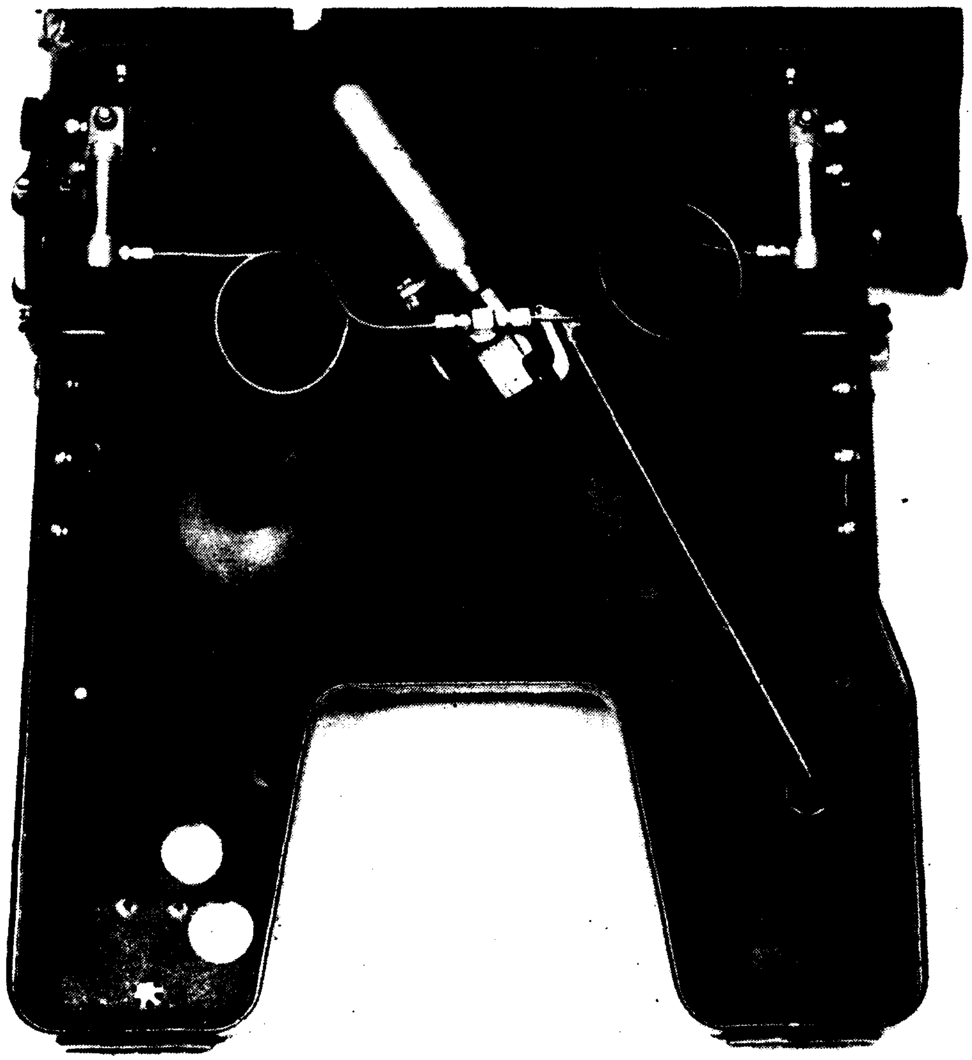

Figure 10. First Prototype XV Harness–Underneath Survival Kit Lid–
Manual/Automatic Release Hardware

Figure 11. Second Prototype XV Harness—Front View

Figure 12. Second Prototype XV Harness–Front View–with Harness Mounted Life Support Gear

Figure 13. Second Prototype XV Harness–Side View–
with Harness Mounted Life Support Gear

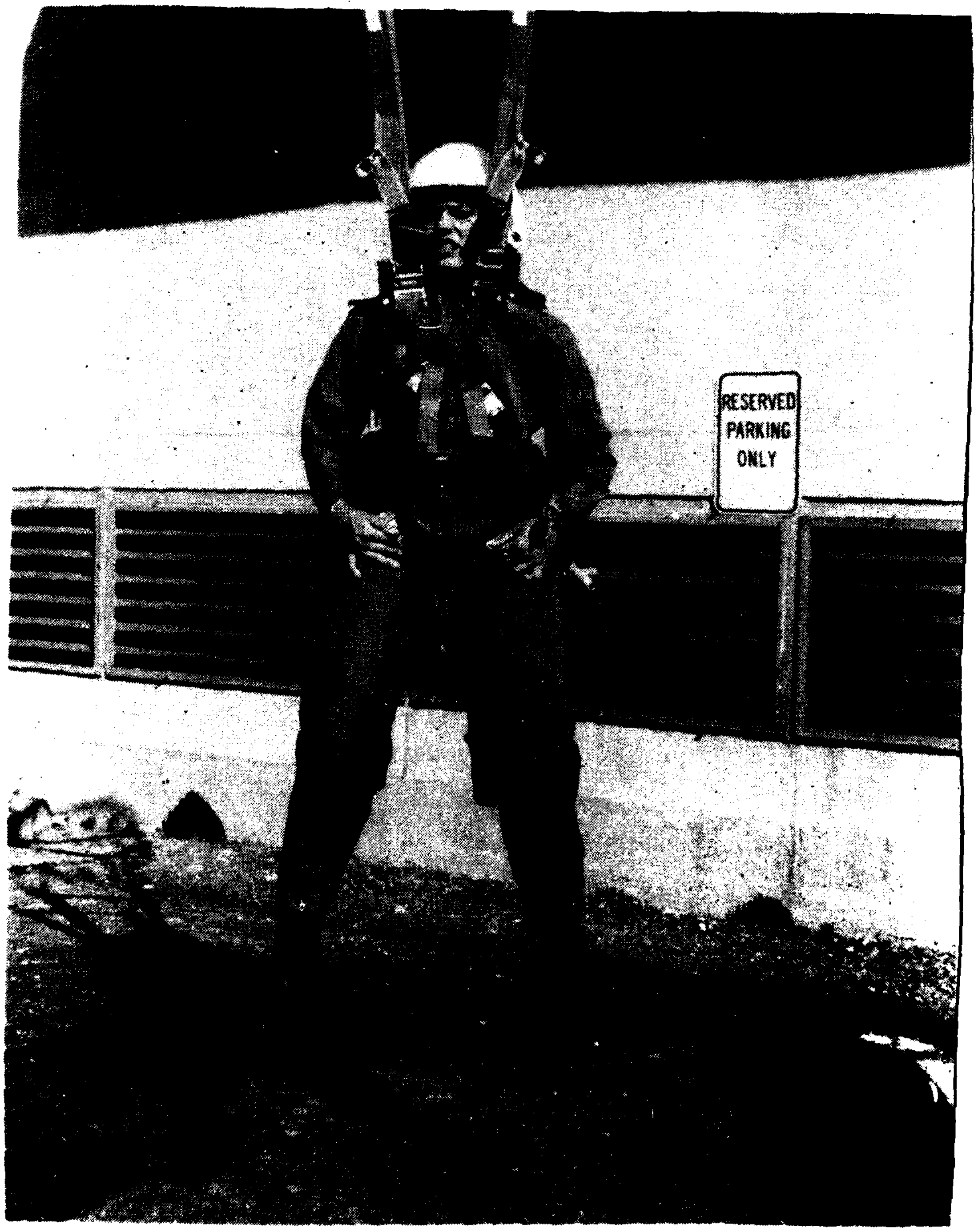

Figure 14. Second Prototype XV Harness—Parachute Suspension

Figure 15. Third Prototype XV Harness—Side View—Left

Figure 16. Third Prototype XV Harness—Side View—Left—with Seat Fittings

Figure 17. Third Prototype XV Harness—Side View—Right

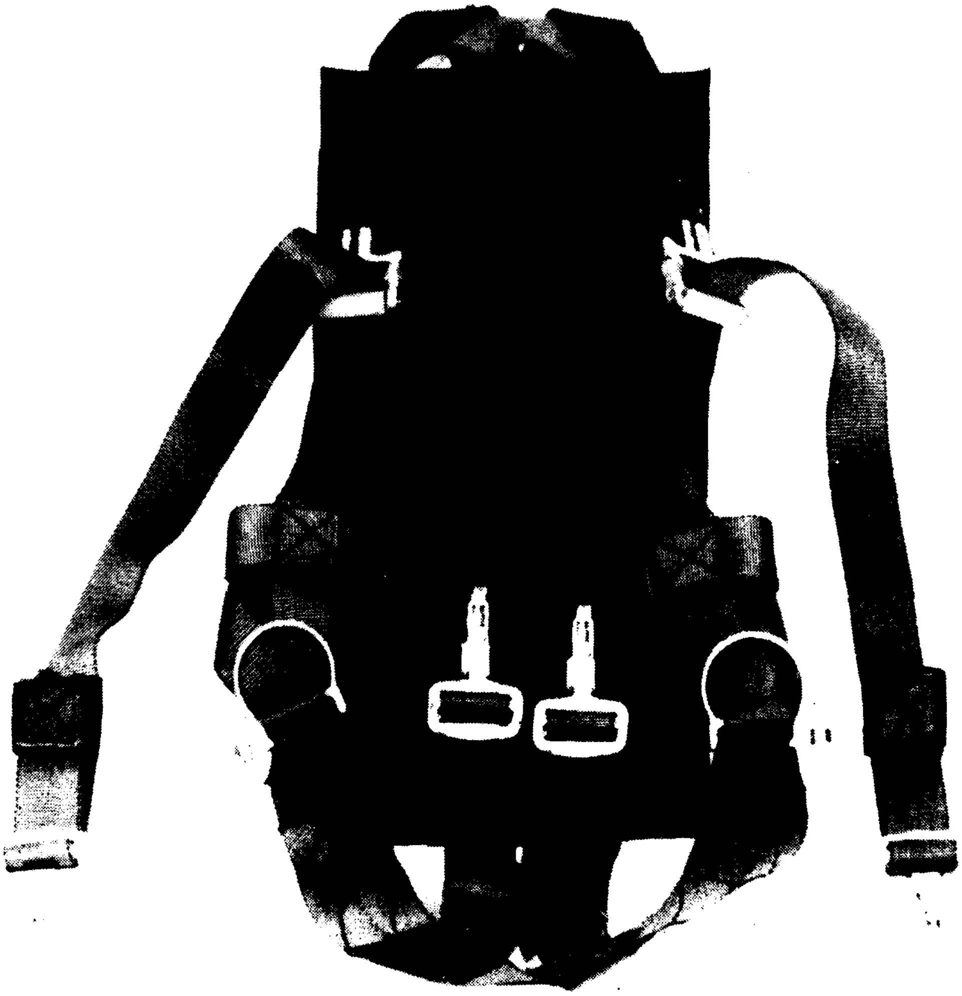

Figure 18. Third Prototype XV Harness–Front View

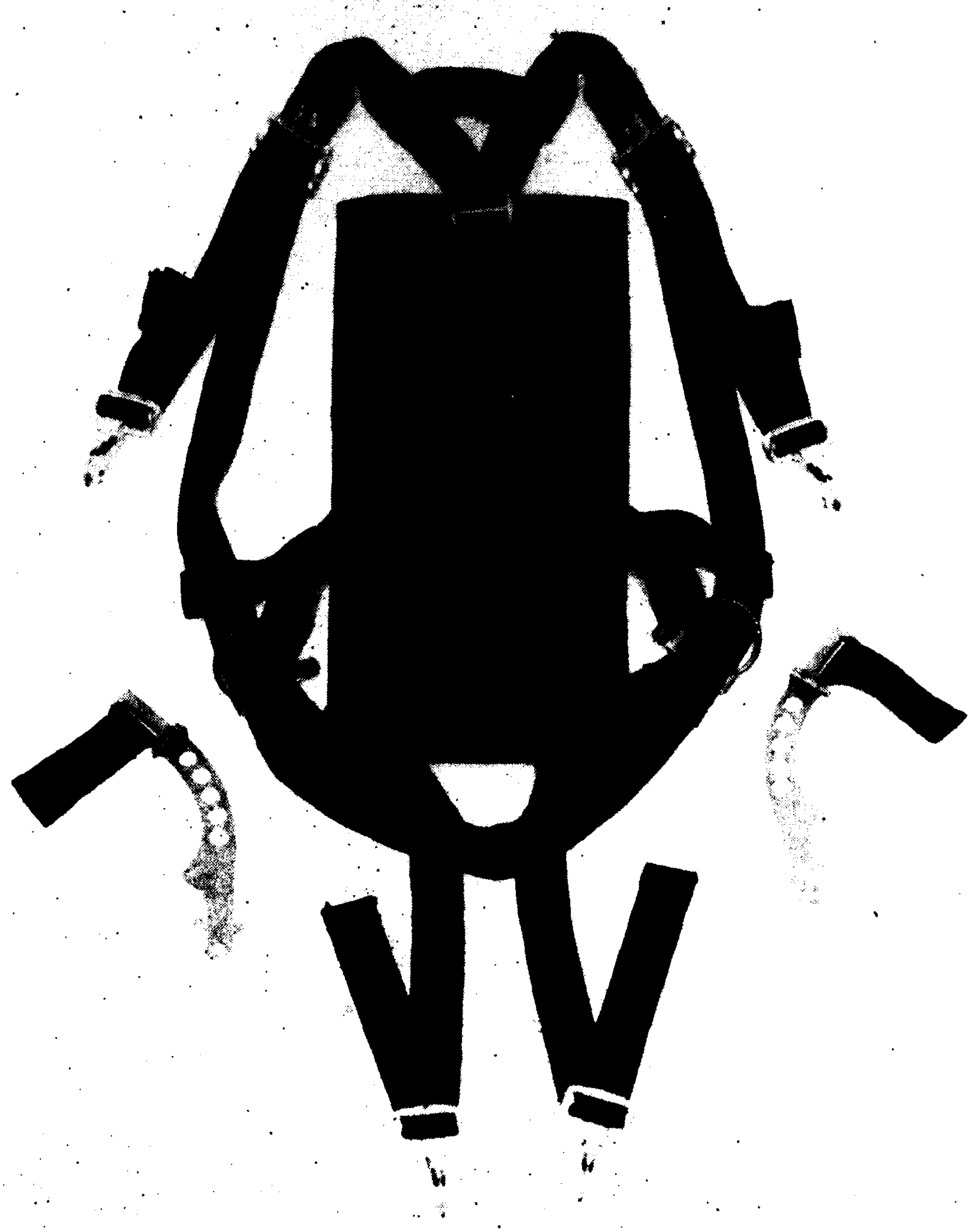

Figure 19. Third Prototype XV Harness—Back View

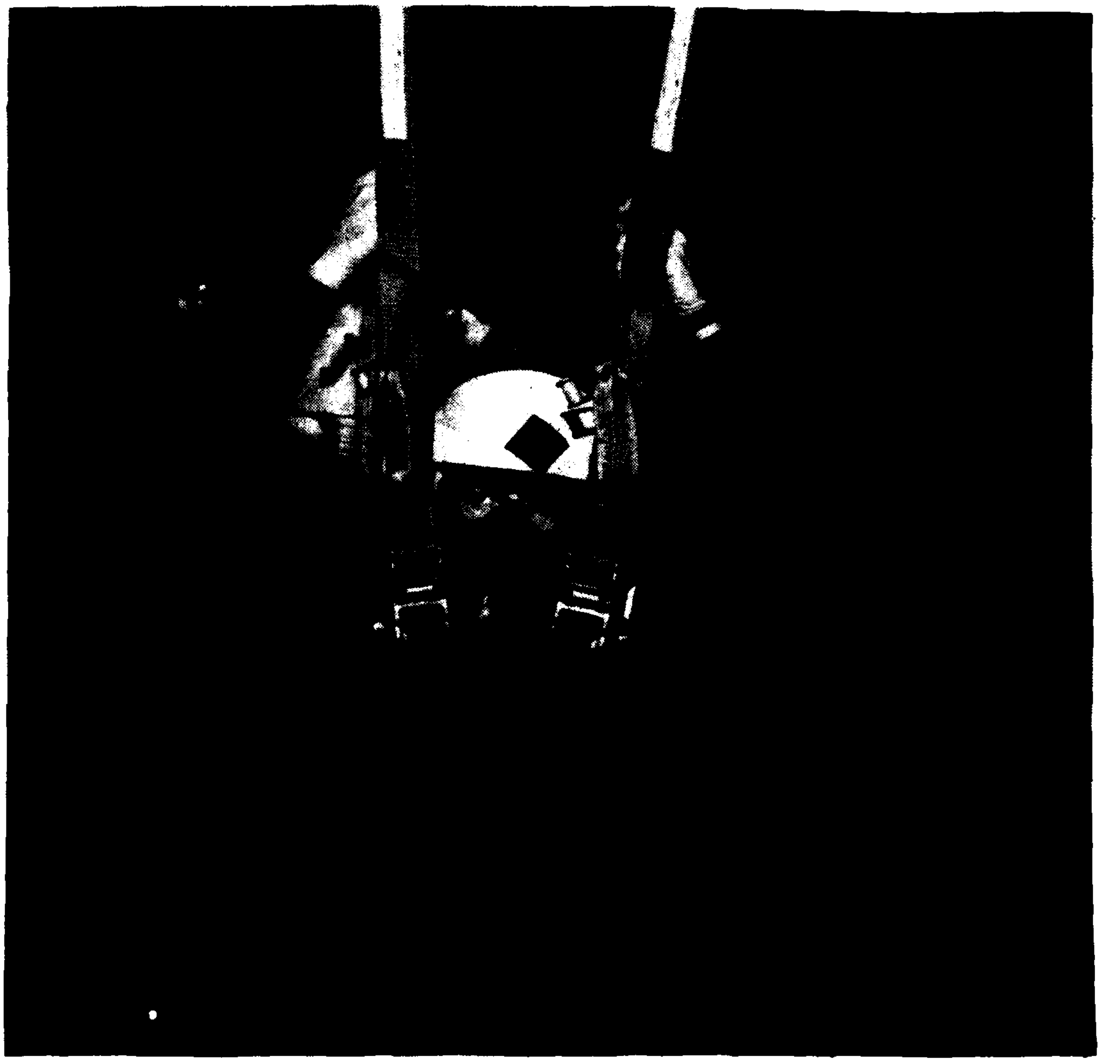

Figure 20. Third Prototype XV Harness–Parachute Suspension

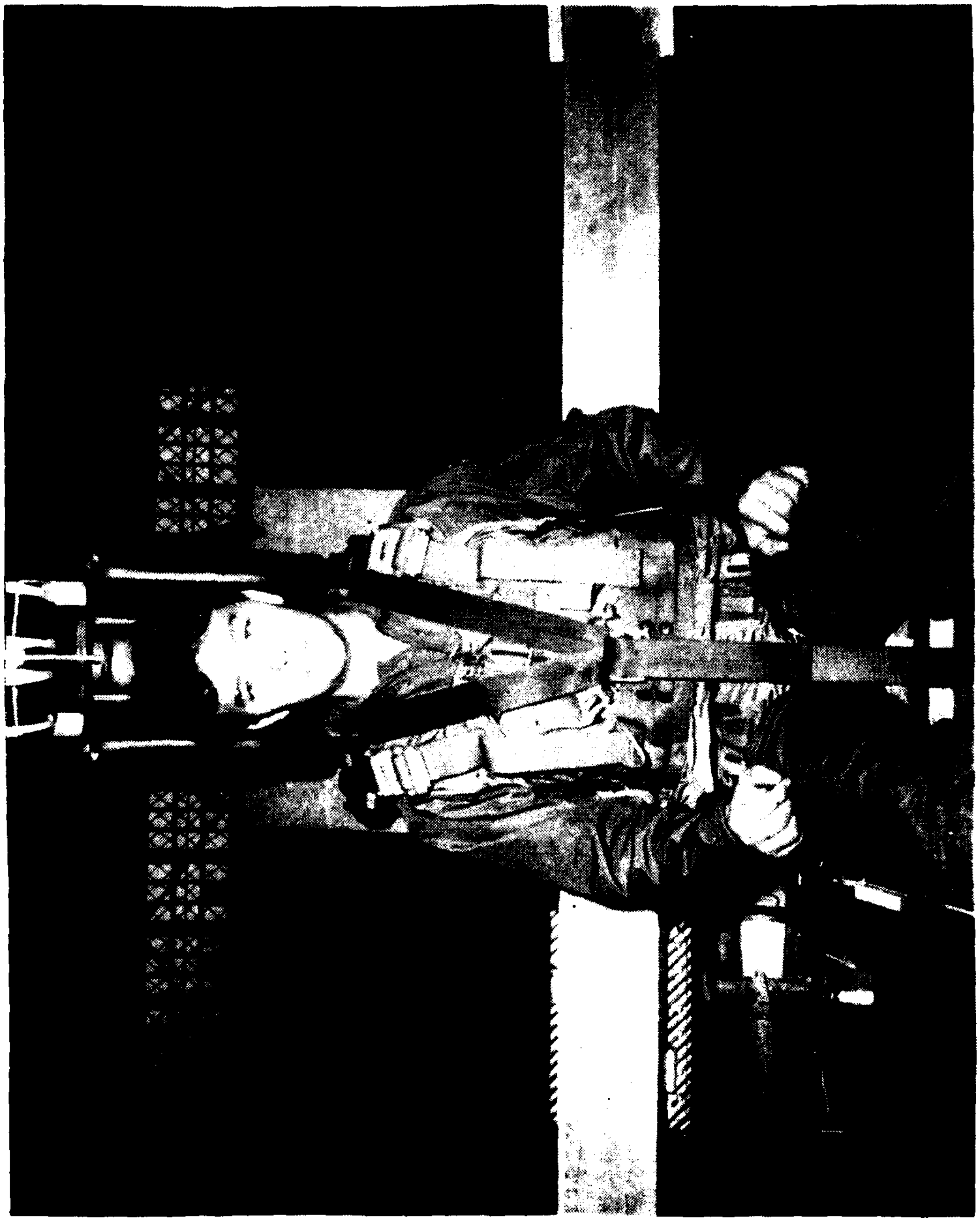

Figure 21. 'Y' Strap with MA-2 Harness

Figure 22. Measuring Head Position on NADC "Rotisserie"

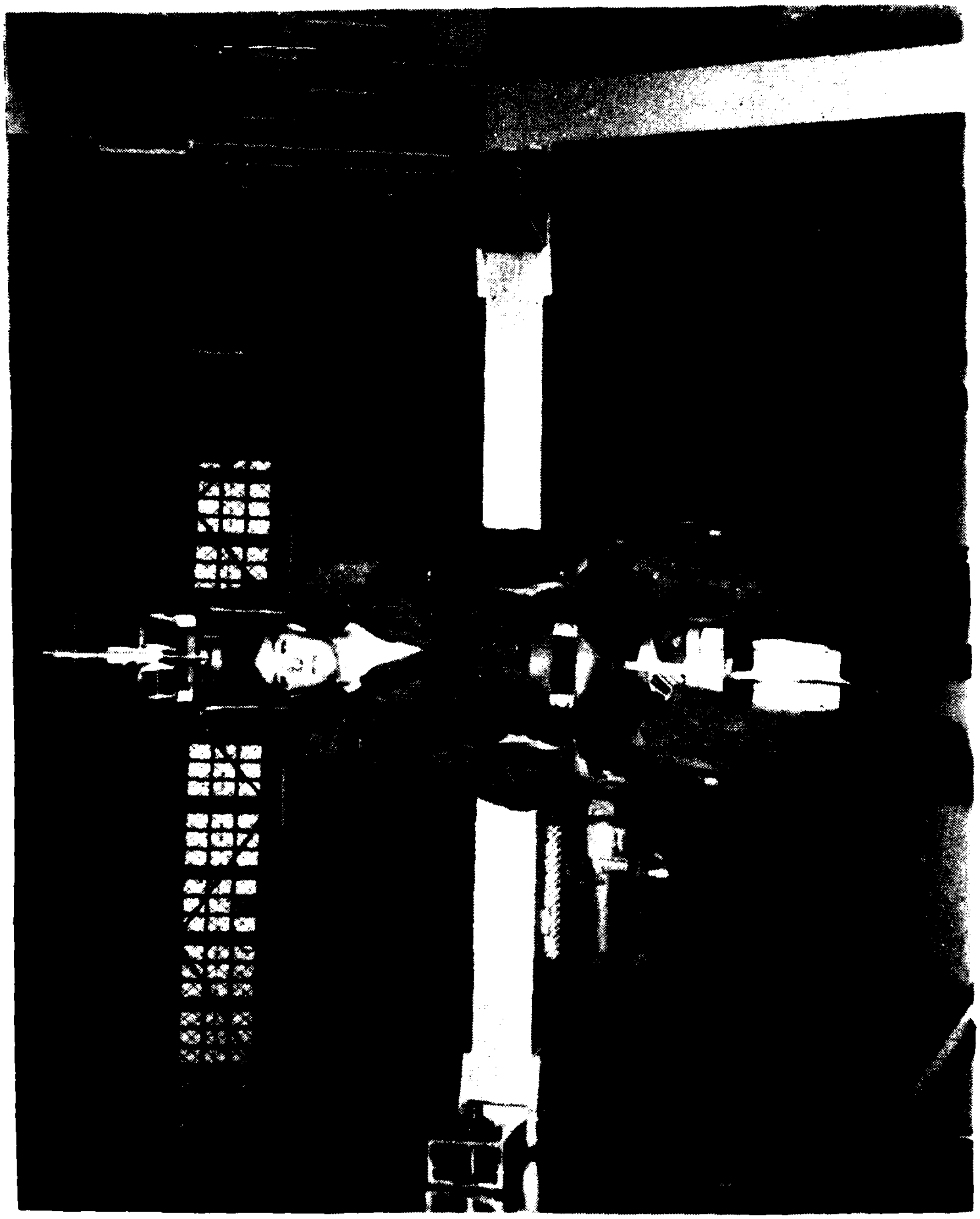

Figure 23. Fiberglas Lap Belt "Bearing Pad"

Figure 24. "Bearing Pad"—Closeup

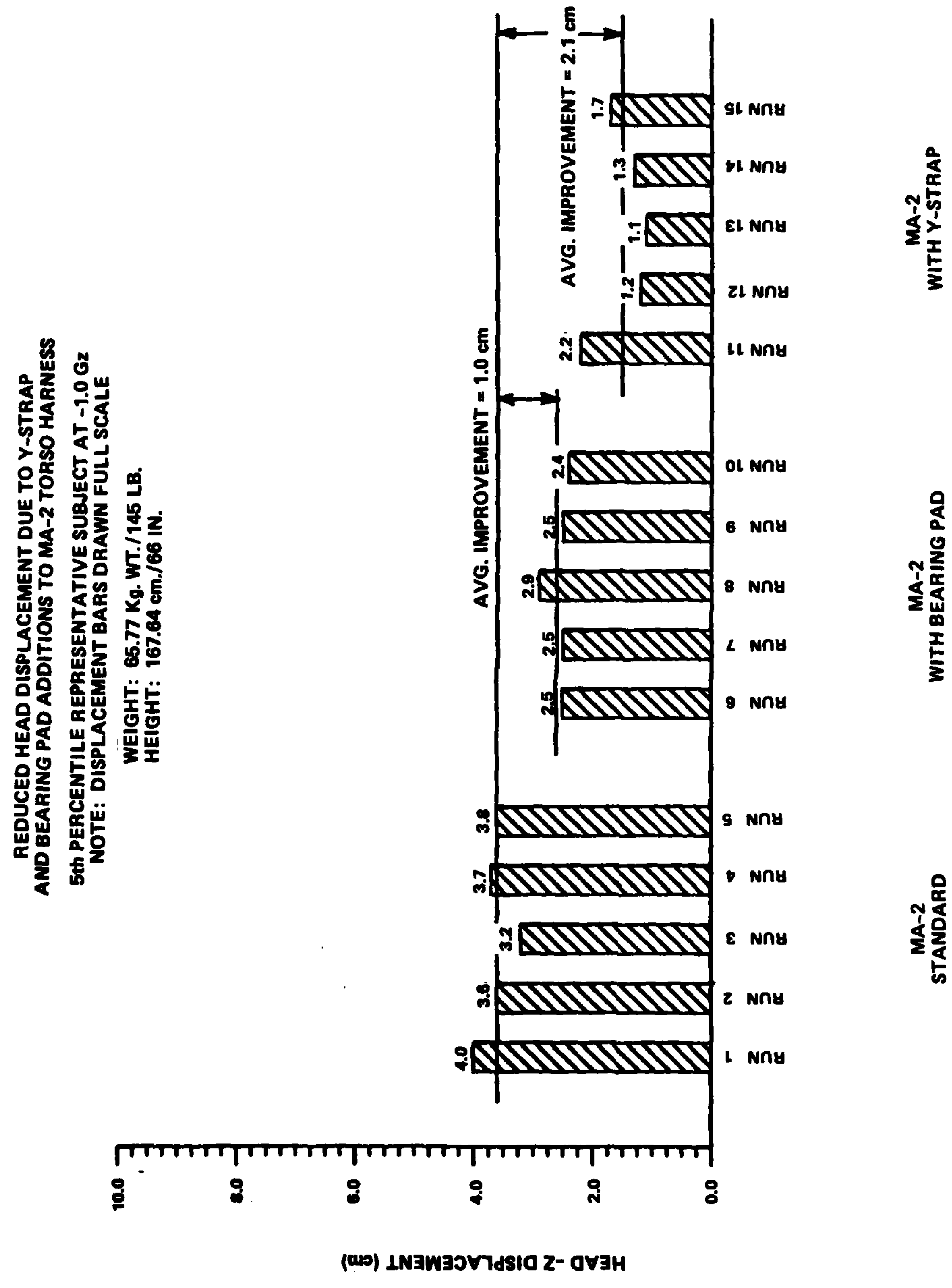

Figure 25. Head Displacement at -1Gz Using 5th Percentile Test Subject

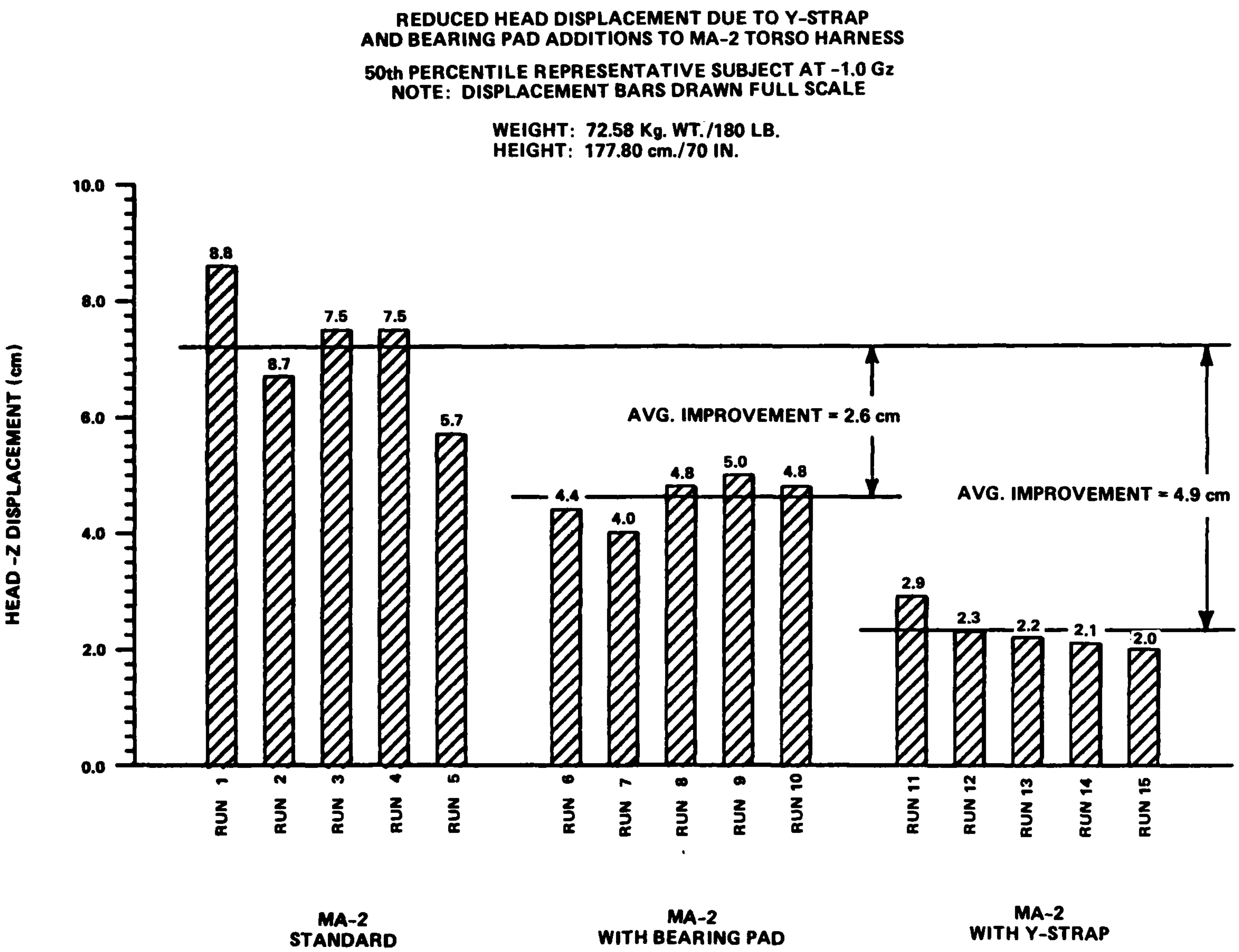

Figure 26. Head Displacement at -1Gz Using 50th Percentile Test Subject

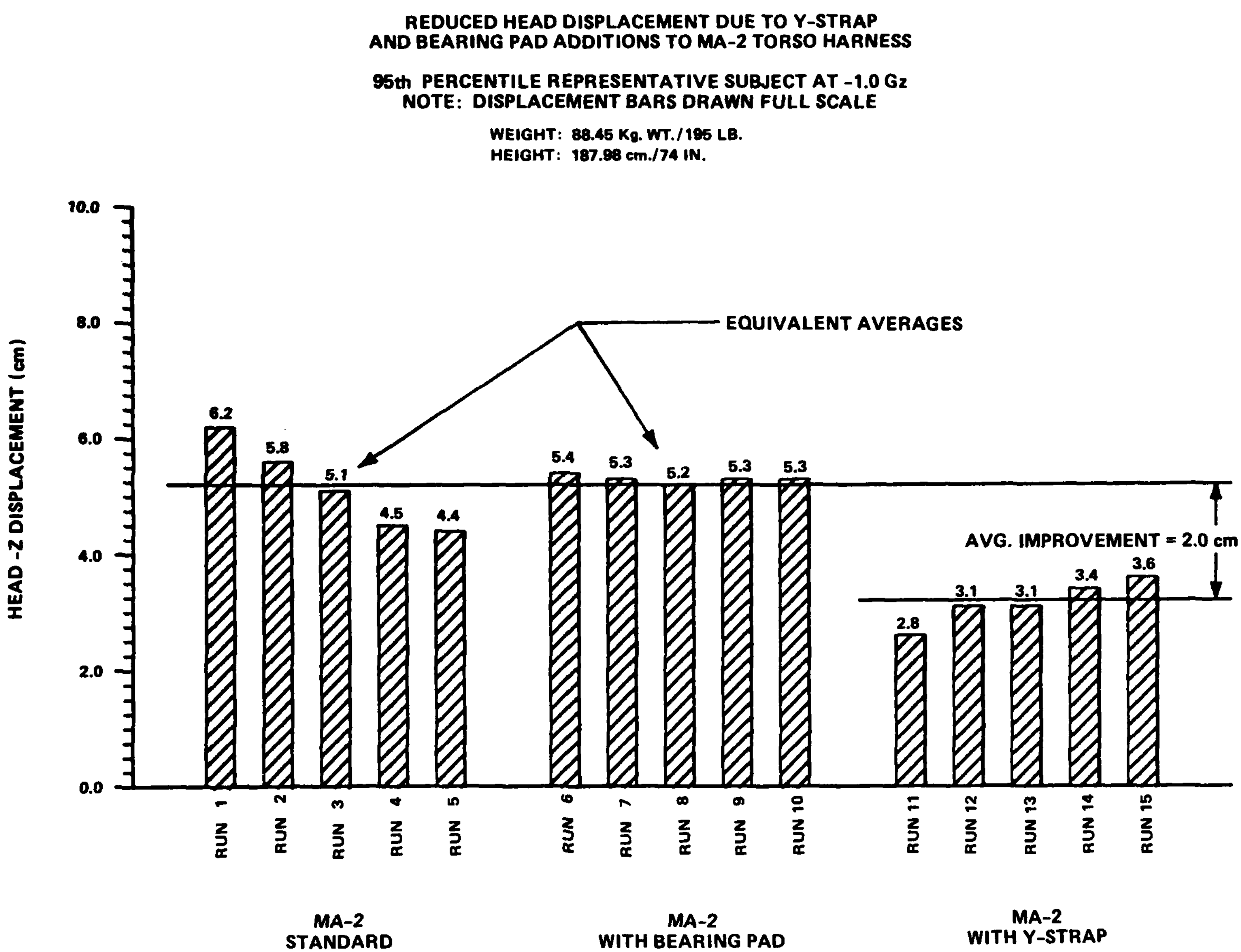

Figure 27. Head Displacement at -1Gz Using 95th Percentile Test Subject

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